

DESIGN AND CONSTRUCTION OF PRECAST BENT CAPS AT TXDOT

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Gregg Freeby, P.E.

Bridge Division, Texas Department of Transportation

125 E. 11th Street, Austin, TX 78701

Phone (512) 416-2192, Fax (512) 416-2557, GFreeby@dot.state.tx.us

Michael Hyzak, P.E.

Bridge Division, Texas Department of Transportation

125 E. 11th Street, Austin, TX 78701

Phone (512) 416-2184, Fax (512) 416-2402, MHyzak@dot.state.tx.us

Ronald D. Medlock, P.E.,

Bridge Division, Texas Department of Transportation

125 E. 11th Street, Austin, TX 78701

Phone (512) 416-2518, Fax (512) 416-2354, RMedloc@dot.state.tx.us

Kenneth Ozuna, P.E.,

Houston District, Texas Department of Transportation

8100 Washington Avenue, Houston, TX 77251

Phone (713) 802-5435, Fax (713) 802-5350, KOzuna@dot.state.tx.us

John Vogel, P.E.

Houston District, Texas Department of Transportation

8100 Washington Avenue, Houston, TX 77251

Phone (713) 802-5235, Fax (713) 802-5350, JVogel1@dot.state.tx.us

Lloyd M. Wolf, P.E.

Bridge Division, Texas Department of Transportation

125 E. 11th Street, Austin, TX 78701

Phone (512) 416-2279, Fax (512) 416-2557, LVolf@dot.state.tx.us

ABSTRACT

The Texas Department of Transportation (TxDOT) is increasing the use and advancing the state of the art of precast bent caps for bridges. Use of precast bent caps helps build bridges in congested and limited access work zones, and it helps minimize traffic disruptions and improve work zone safety by moving work out of the work zone. Design of precast bent caps requires special attention to the cap-to-column connection. TxDOT has sponsored research to analyze cap-to-column behavior and improve design methodology. Projects built by TxDOT that use precast bent caps demonstrate the design methodology used, including implementation of research results.

INTRODUCTION

The Texas Department of Transportation (TxDOT) has developed the innovative design methodologies and construction practices for precast bent caps described in this paper. Precast bent caps help address modern bridge building challenges:

- construction in congested urban settings is becoming more difficult.
- concerns about traffic delays and public safety in such congested construction zones have intensified.
- costs associated with traffic control and with disrupted traffic flow have increased substantially.

Fabricating the caps in a controlled environment also improves quality and durability. Precast bent caps are gaining popularity in TxDOT bridges, and their design, especially regarding the cap-to-column connection, has evolved through experience and research:

- The Redfish Bay and Morris and Cummings Cut bent caps used full depth slots and a 5-inch bottom square recess over each pile, with U-shaped reinforcing bars protruding from the piles and grouted into the slots. The connections were configured as simple pins.
- The US 290 Ramp E-3 bent cap was redesigned as a precast simple member, with post-tensioning to tie the cap to the columns with a pinned connection.
- For the Pierce Elevated rehabilitation, the original superstructure was cut off from just beneath the bent caps, with new post-tensioning bars chemically anchored into the original columns and later grouted into new precast caps after stressing. In-plane bending moments at the top of the column were discounted, with the assumption that the precast bent cap would form a hinge.
- TxDOT-sponsored research developed a family of precast bent-cap connection details for low-to-moderate moment demand at the top of the column and associated design methodology and specifications for material properties, placement of caps, and grouting procedures.
- Incorporating research findings, the Lake Ray Hubbard bent caps used a simplified connection and column analysis to determine the worst case of a pinned or rigid connection at the top of the column, with loads factored to improve ductility. Confining reinforcement around each connection zone in the cap was provided to enhance ductility and increase section strength.
- The Lake Belton Bridge, currently under construction, will employ precast hammerhead bent caps with relatively high moment demands. The caps were designed using an extrapolation of research results.

TxDOT expects demand for precast bent caps to increase. TxDOT's work represents the state-of-the-art in precast bent caps. Precast bent caps help build better bridges, especially for complex jobs in congested environments or over water. As evidenced by contractor's requesting their use, precast caps improve bridge constructibility and economy. TxDOT's precast bent cap design philosophy has evolved and will continue to do so.

PURPOSE

The purpose of this paper is to share information on the use of precast bent caps in bridges in Texas by describing specific bridge projects and research as well as TxDOT's evolving design methodology.

REDFISH BAY AND MORRIS AND CUMMINGS CUT BRIDGES PROJECT

The Redfish Bay and Morris and Cummings Cut Bridges constructed in 1994 are good examples of early precast bent cap use by TxDOT. These bridges replaced a cast-in-place reinforced concrete causeway that crossed coastal tidelands and marshes between the Texas mainland and Mustang Island. Severe chloride-induced deterioration required replacement of the existing reinforced concrete slab and girder structures. Because of a detour length of 60 miles and because the bridges provided one of only two routes from the mainland to the island and the city of Port Aransas, rapid bridge replacement was imperative to minimize traffic disruption.

With lengths of 2,020 feet for Redfish Bay and 415 feet for Morris and Cummings Cut, the bridges included 46 spans ranging in length from 45 to 55 feet each. As originally designed, the replacement bridges included a precast, prestressed double-tee superstructure supported by cast-in-place rectangular bent caps on precast, prestressed trestle piles. However, the contractor requested to use precast bent caps to accelerate construction and minimize concrete casting over water.

Phased construction was employed to maintain traffic over the causeway. Two precast bent designs were required for the overall 46-ft bridge width. The caps were 3 feet, 0 inches wide by 2 feet, 9 inches deep and 25 feet, 9 inches or 18 feet, 7 inches long (length of cap across the roadway width). The connection included a pair of full-depth slots and a 5-inch deep bottom square recess precast into the caps over each pile location. (See Figures 1, 2, and 3.) Each pile was cast to encase four 1½-inch diameter by 3-foot, 0-inches long corrugated galvanized steel ducts at the top of the pile. The piles were driven with the aid of a steel frame that served as a template to ensure proper location and fit-up for the precast connection. The piles were designed to be driven to an elevation consistent with a 3-inch embedment into the cap. After driving the piles, two U-shaped epoxy coated Grade 60 reinforcing bars were epoxy-grouted 2 feet into the ducts at the top of the piles. The ducts were made 1 foot longer than the required bar embedment to allow for some pile break-back in the field if resistance was encountered earlier than expected. The caps were lowered onto the piles so that the looped ends of the connection reinforcement projected 2 feet into the precast voids. The design originally called for shims as the means of cap support between the piles and the bottom of the cap recess. Problems with movement of these shims required a change to friction collars at the exterior piles for cap support. After the caps were set at the proper grade, the bottom openings were sealed with plywood forms and a special concrete mix was placed from above. The concrete mix requirements included a 4000-psi compressive strength at 48 hours, ¾-inch maximum aggregate, a cement content of 8 sacks/cubic yard, and maximum shrinkage of 0.1%.

All 44 bent lines (a total of 88 precast caps) were successfully precast and constructed. The use of precast caps reduced the construction time from an estimated 25 months to 16 months and also resulted in reduced traffic control costs.

US 290 RAMP E-3 PROJECT

This project was constructed in 1996 in Austin, Texas. Due to right-of-way restrictions, the roadway design for the eastbound exit and entrance ramps required the use of a braided ramp configuration. For this particular braided ramp configuration, the lower roadway provides an exit ramp and the upper roadway provides an entrance ramp. The upper roadway is a bridge with an overall width of 24 feet and is supported with AASHTO Type IV prestressed concrete beams. In order to provide sufficient vertical and horizontal clearance with the lower roadway, an inverted tee straddle cap was used. The columns supporting the cap are 3-foot, 0-inch square columns spaced 33 feet apart. The inverted tees have an overall depth of 79 inches with a flange depth of only 22 inches.

During construction of the project, a need became apparent to construct the eastbound exit ramp (lower roadway) and open it to traffic as soon as possible. After construction of the exit ramp, the project engineer realized that the formwork for the construction of the inverted tee cap of the entrance ramp would block traffic on the exit ramp, making it necessary to close the exit ramp during construction. This was expected to take several weeks. Traffic engineers estimated that closing the exit ramp for this length of time would have serious negative impacts on the traffic flow on the main-lanes of US 290. Therefore, they decided to develop a precast cap to reduce the closure time from several weeks to just a few hours.

Changing from the original cast-in-place cap to a precast cap necessitated reconsideration of the design, especially the connection. The cap was originally designed as a simply supported member so the connection could be designed as a pinned connection. High-strength threaded bars were installed in the columns. Precast voided vertical ducts in the cap allowed the precast cap to be post-tensioned to the tops of the columns to form the connection. (See Figure 4)

The inverted tee straddle cap was prefabricated adjacent to the bridge site using conventional forming and casting methods. The cap was fabricated using TxDOT Class "C" concrete, which has a 28-day compressive strength of 3600 psi. After a curing period of four days, the cap was removed from the forms and placed directly onto the columns in a single operation. Next, the cap was connected to the supporting columns using vertical post-tensioning. One-and-a-half-inch diameter Grade 150 Dywidag-threaded bars were used for the post-tensioning.

Two cranes were used to place the cap, which weighed nearly 75 tons. (See Figure 5.) The cap was temporarily supported on plastic shims. The gap between the cap and column was sealed on three sides using plywood forming. The void was then filled by hand-placing dry-packed grout. Once this operation was complete and the dry packed grout had achieved a strength of 4000 psi, the Dywidag bars were stressed to 146,000 pounds each. After all post-tensioning was complete, the post-tensioning bars were grouted.

This construction technique reduced the total time for closure of the exit ramp for cap erection and post-tensioning to approximately 6 hours. The success of this project demonstrated to TxDOT the advantages in speed of construction of using precast substructure elements. However, it also identified the need for simplified precast connection methods: a method using conventional reinforcing and eliminating the need for specialized hardware.

PIERCE ELEVATED PROJECT

The Pierce Elevated section of IH 45 in the Houston central business district needed replacement of 113 spans due to deterioration of the superstructure, but the columns were still serviceable. Use of a conventional TxDOT bridge system, consisting of a precast superstructure and cast-in-place bent caps, would have required in excess of a year and a half to complete construction. User delay costs were estimated at greater than \$100,000 a day in urban Houston, so TxDOT bridge designers chose precast bent caps as a means to speed up construction. The use of precast bent caps allowed the Pierce Elevated job to be completed in just 95 days rather than the 548 days needed for conventional construction.

However, use of precast bent caps posed two problems:

- No comprehensive design methodology existed for beam-to-column connections.
- Precast bent cap connection details that install into existing columns were needed for compatibility with conventional bent cap reinforcement details because any deviation from conventional bent cap steel detailing would be detrimental to the cost-competitiveness of a precast system.

TxDOT considered two approaches to address the uncertainties posed by the precast connection:

- Partially demolish the columns just enough to expose the reinforcing steel, and then cast the reinforcing steel into a “blockout” provided within the precast cap. This idea was abandoned due to possible column damage during demolition.
- Develop a detail in which post-tensioning bars are chemically anchored into the existing columns. This option was selected.

Post-tensioning offered distinct advantages. TxDOT could pay for post-tensioning bar installation using standard specifications along with added plan notes to control their testing. The shop drawing process (required for post-tensioning bars) allowed review of the contractor’s chemical anchorage system, installation methods, and grouting procedure. Shop drawings proved a valuable tool for keeping lines of communication open between suppliers, contractors, and TxDOT. Shop drawings also provided the opportunity to improve the plan details as new issues developed.

Design began with assumptions about the load transfer through the precast connection. The first assumption was to discount the in-plane bending moments at the top of the column. This seemed reasonable because the transverse moments at the top of the column were small. The connection was designed for out-of-plane construction moments and final out-of-plane dead- and live-load moments. Review of archival concrete strength reports for each of the existing columns revealed that the concrete used in the original structure was typically 25% stronger than the contract required, and this was beneficial to the design. An ultimate strength column analysis revealed that the controlling design factor was the concrete strength of the existing columns. The stress levels of the post-tensioning bars were checked for the worst load cases.

A chemical anchoring system was used to develop the full capacity of each bar. No problems with durability or cold weather behavior of the connector anchorage to the column are expected because the chemical anchorage is located deep within the mass of concrete where water is not available and because the fillers used within polyester resin matrix make its coefficient of expansion similar to concrete. Final properties and installation method of the anchoring system were verified in shop drawing review and approval. To establish quality control, testing of the stress bars was controlled with plan notes, including a delay to the job if any bar failed.

Steel shim packs were set atop columns, and then the precast caps were lowered onto the shims, with the bars passing through embedded ducts within the cap. Proper cap elevation and cross slope was set and verified prior to grouting. Grout was introduced into the air space between the top of column and bottom of cap, including the annulus of the embedded ducts. A single hoop of reinforcing steel was included on top of the column to preclude grout spalling due to high edge stresses. A nominal post-tension force was placed on each bar before the chemical anchorage setup.

See Figure 6 for bent-cap-to-column details for the Pierce Elevated project.

Quality control issues associated with precast cap to existing column connections were considered and addressed in design:

- A wire saw cut was chosen to address concerns that demolition of the existing caps might result in damage to the columns and to provide a clean and relatively level surface at the top of column. (See Figure 7)
- To ensure fit between the prefabricated bent caps and the as-built columns, a complete survey of the existing bridge including span lengths, column locations, sizes and bent cross slopes was performed. Further, oversize ducts were cast within the precast cap to provide some tolerance.

Although a number of special instructions for the contractor were needed, the short schedule precluded publication of a special specification. Instead, plan notes were used to supplement TxDOT's standard specifications. TxDOT's standard specification for prestressing was used to pay for the connection.

Shop drawing submittals and approvals ensured clear understanding of job requirements between TxDOT and the contractor. In addition to construction details, shop drawings for special construction operations included notes on demolition, surface preparation, installation of the epoxy anchored stress bars, and grouting. The shop drawing submittal and approval process proved valuable because it allowed TxDOT to review the contractor's methods and to redirect the contractor as needed.

RESEARCH—PROJECT 1748

The US 290 Ramp E and Pierce Elevated projects demonstrated the need to develop a family of precast bent-cap connection details for typical short-span bridges with low-to-moderate moment demand at the top of column. TxDOT sponsored research project 1748, "Development of a Precast Bent Cap System" (1), which was conducted by the University of Texas, Austin. The project advisory panel included designers, fabricators, and representatives from the construction industry. Researchers performed a literature review of precast connection technology and considered past work within TxDOT and other states that have developed precast substructure details. They developed three types of connection details for connecting rectangular and inverted tee bent caps to cast-in-place columns or trestle piles: grouted pockets, grouted vertical ducts, and bolted connections. Because of the partnership with the advisory panel, the proposed details are highly economical, constructible, and durable.

The process of developing details for test specimens revealed numerous uncertainties associated with transfer of connection forces between bent caps and columns. These included bar anchorage within grout pockets or grouted vertical ducts, interlock of grout pockets and ducts within precast caps, failure modes, and the influence of confinement on connection behavior.

Researchers performed connector tests on full-scale bent cap mock-ups to investigate development of connectors within a bent cap. They conducted 32 pullout tests on single-line and double-line grout pockets as well as grouted vertical duct specimens. Initial tests provided data on grout types and the depth at which failure transitioned from a concrete breakout to yield of the connector steel. Several tests allowed examination of the effects of straight versus headed bars, two bars loaded simultaneously, multiple grout pockets, and anchorage behavior confining effects.

The first phase of testing enabled development of anchorage design provisions for single and multiple epoxy-coated, headed bars embedded in grout pockets and ducts. The first phase of research also provided preliminary information about grout mixes and placement of grout, which aided in the development of grouting specifications.

Next, researchers built and tested four full-scale single column and cap specimens. They tested a single-line grout pocket, double-line grout pocket, grouted vertical duct, and a bolted connection (see Figures 8 – 12). Specimens were loaded to service-level, factored-load level, and failure-level to verify design provisions and specifications that were developed through the initial testing program. These tests confirmed the adequacy of the anchorage provisions that were developed following initial testing. Results indicated that the anchorage provisions were somewhat conservative, but because calculated embedment depths in precast bent-cap elements were not prohibitively long, anchorage provisions were not modified. The testing also provided more information about grout behavior and placement procedures, enabling further refinement of the proposed grout specifications.

Finally, a bridge contractor built a full-scale trestle-pile bent and a three-column bent and field-tested them to first yield of connectors. These tests verified the constructibility of the connections and enabled the research team to observe how the proposed grouting specification worked under real world conditions. The team observed and reported on construction tolerances for multiple connections, assembly and grouting of multiple connections in realistic field conditions, including adverse weather conditions, and contractor/engineer interaction.

Following testing, researchers prepared a comprehensive procedure for design of precast bent-cap connections. The procedure includes design provisions for bars anchored in grouted ducts, bars embedded in grout pockets, and other detailing provisions. In addition, the procedure presents a comprehensive connection specification for precast bent-cap connections that addresses material properties, placement of caps, and grouting procedures.

LAKE RAY HUBBARD PROJECT

In 2000, TxDOT began replacement of the narrow two-lane crossing of SH 66 over Lake Ray Hubbard: the new bridges would be a pair of conventional prestressed concrete I-beam bridges with lengths of 10,280 feet for the westbound structure and 4,360 feet for the eastbound structure. The westbound bridge was built on an alignment just

north of the existing structure. Traffic was shifted to the westbound structure when it was complete, and then the existing structure was removed. Then the new eastbound structure was built on the former alignment.

The contractor asked to precast the substructure bent caps as an alternative to the original cast-in-place design to accelerate construction, avoid the difficulties in handling formwork and materials over water, and minimize the exposure of workers to power lines near the south side of the eastbound structure. The power lines precluded use of barge-mounted cranes, so a temporary construction bridge allowed cranes to operate in the water on a well-controlled path parallel to the new eastbound bridge. (See Figure 13.)

To achieve a strong, ductile, durable, and constructible precast cap-to-column connection, designers based the precast bent cap design on project 1748. TxDOT first designed a large void in the cap to facilitate construction tolerances, but grout volume for the void was cost prohibitive, so TxDOT changed to vertical corrugated ducts, which reduced the grout volume by 60%. Six #11 Grade 60 reinforcing bars in the top of the cast-in-place columns project into 4-inch diameter ducts precast full-height into the cap. Spiral confinement reinforcement in the cap around the perimeter of the connection zone improves strength and ductility and provides service-level crack control. (See Figure 14)

The connection was designed as follows:

1. Frame analysis was used to determine connection actions. Connection and column forces were determined by the worst-case boundary condition of a pinned or rigid connection at the top of the column. Consistent with the research recommendations for an additional factor of safety, load factor connection forces were increased by 30%.
2. A trial connector configuration was selected based on spacing, clearance, and minimum connection reinforcement requirements. The configuration was also patterned to maximize the eccentricity of the bars and to fit within the limits imposed by the bent cap flexural steel.
3. The connector configuration was analyzed by evaluating strength and serviceability performance. Strength was evaluated in terms of an axial load-bending moment response of the round cross section with the selected connector configuration. Shear friction at the bedding layer and joint shear were also evaluated. Serviceability performance was evaluated by traditional elastic analysis under service loads. Because moments were low, connectors would not be in tension, so associated crack control provisions did not govern.
4. Uncoated Grade 60 reinforcing steel was selected for the connectors because the structure is in a non-corrosive environment. Project 1748 findings for reinforcement development length in grouted pockets and vertical ducts were used to determine bar extensions into the bent and into the column.
5. Confining spiral reinforcement for each connection was provided to enhance ductility and increase section strength, as recommended by Project 1748.

To facilitate rapid cap production, TxDOT allowed its standard four-day cure time to be interrupted by a maximum of 2 hours to facilitate removal of caps from the forms if a flexural strength of 355 psi and compressive strength of 2500 psi were achieved. Similar column curing allowances were permitted for setting the caps.

Designers used project 1748 recommendations for grout type, placement, and testing. Project 1748 had developed a specification for grout performance based on the requirements of ASTM C-1107, "Packaged/dry hydraulic-cement grout (nonshrinkable)," augmented by specific requirements:

- Mechanical—Compressive strength (ASTM C-109, 2-inch cubes): 1 day=2500 psi, 3 days=4000 psi, 7 days=5000 psi, 28 days=5800 psi.
- Compatibility—Expansion (ASTM C-827 & ASTM C-1090): Grade B or C ~ expansion per ASTM C-1107). Modulus of elasticity (ASTM C-469): $2.8 - 5.0 \times 10^6$ psi. Coefficient of thermal expansion (ASTM C-531): $.0 - 10.0 \times 10^{-6}$ /deg F.
- Constructibility—Flowability (ASTM C-939; CRD-C 611 Flow Cone): Fluid Consistency Efflux Time of 20 – 30 seconds. Set time (ASTM C-191): Initial=2.5-5.0 hours and Final=4.0-8.0 hours.
- Durability—Freeze thaw (ASTM C-666): 300 cycles, RDF 90%.

Grout with metallic formulations, chlorides, and external additives was prohibited. Grout was pressure pumped from the bedding layer, using the open tops of the vertical ducts at the top of cap as an indicator of a fully grouted connection. Grout frothing or foaming was not allowed.

An option to precast the bearing seats was provided, and the contractor chose to do so. Cast-in-place seats provide flexibility and account for height errors, but precast bearing seats would not require casting over water. With either approach the contractor could choose a level cap and variable bearing seat height to accommodate the cross-slope of the roadway.

The contractor precast the bents at the eastern end of the bridge. Pre-tied reinforcing cages were laid into steel forms and concrete was placed. When sufficient strength was achieved, the caps were removed and stored to continue curing. Drilled shaft and column construction were conducted while precasting operations continued. A

special template formed the final lift of concrete for the columns and helped accurately locate both the columns and the projecting connection reinforcing bars. When the columns had cured sufficiently, the caps were loaded onto barges and transported for erection. Friction collars were placed on the columns to support a work platform and to provide temporary support and grade adjustment for the caps. Once the cap was at the desired grade, special round collar forms were placed at the bedding layer. These forms had one input for the pressure grouting and three vents to ensure full grouting of the bedding layer. Workers finished the top surface of the grout once it reached the top of the vertical ducts at the top of the cap.

The contractor averaged one in-place bent per day compared to nearly one per 5 to 7 days for cast-in-place construction, saving time for 43 bents of about half a year. In addition, work zone safety was increased because 80% of the work associated with bent construction was performed on the ground instead of in the air over water. Finally, a higher quality product resulted since contractor and inspection personnel could work more easily from the ground.

LAKE BELTON BRIDGE PROJECT

In 2002 TxDOT began construction to replace the narrow two-lane crossing of SH 36 over Lake Belton northwest of Temple. The new, wider structure will conform to current roadway geometric requirements, having a total length of 3,840 feet and an overall width of 84 feet, and it will feature a precast, prestressed U-beam superstructure with a hammerhead bent substructure. It also includes precast bent caps for these reasons:

- With 62 identical caps, the necessary repetition is sufficient economic justification for precasting.
- A large amount of construction will need to be staged from the water.
- Because Lake Belton is a flood-control reservoir with potential for widely fluctuating water surface elevation, the bridge will be constructed nearly 50 feet over the normal pool elevation, increasing the difficulty of casting concrete over water.
- While the new structure will be built parallel to the existing one, long detour lengths make lengthy lane closures on the existing structure unacceptable, increasing the need for speedy construction.

Because the Lake Belton Bridge is a large crossing of a lake extensively used for recreation, the substructure design was influenced by aesthetics. Designers replaced the clutter of a typical multi-column substructure with a pseudo-single-column bent design. (See Figure 15) A pair of 60-inch diameter columns/drilled shafts spaced 7 feet on center support the bent cap. A tie beam above the water line connects the two columns together and allows some adjustment of column plan location to fit the cap connection. Durability concerns with precast connections submerged for periods of time and constructibility concerns due to potentially high lake levels dictated cast-in-place construction of columns. The columns have a sloped-column capital in the final 11 inches of column height. Varying in depth from 5 feet, 6 inches to 3 feet, 0 inches, the 39-foot long caps have an arcing bottom soffit outside of the supporting columns, while the cap width is 5 feet, 6 inches at the top and 5 feet, 0 inches at the bottom. The caps symmetrically support four lines of TxDOT Type 54 U-beams that are 120 ft long. The precast cap weight of approximately 70 tons each is nearly equivalent to the weight of each U-beam.

Initially, design concerns focused on the possibility of having relatively high bending moments and tensile forces generated in the precast connections of a single column bent. A post-tensioned connection with threaded rods or bars to overcome these forces would be difficult given the lack of space due to extensive negative moment reinforcing in the top of the cantilevered bent caps. Structural analysis to determine connection actions revealed that design forces would not require a post-tensioned connection. (See Figure 6.)

The connection design is similar to that on the Lake Ray Hubbard Bridge. (See Figure 16.) A pattern of 12 #11 Grade 60 reinforcing bars and 2 1-3/8-inch diameter threadbars in each of the two column to cap connections was specified to provide the requisite load factor strength. Under service loads, no appreciable connector tension is present. The 12 mild steel connectors and 4-1/2-inch diameter vertical corrugated ducts are extended 4 feet, 3 inches and 4 feet, 5 inches respectively into the cap. Not extending full height avoided congestion problems with the negative moment steel in the cap and mitigated durability issues with large exposed surfaces of grout at the top of the cap. The 2 thread bar connectors and associated ducts are extended full height to facilitate temporary support of the cap prior to completion of connection grouting. Each duct has grout input and output tubes that project out the top of the cap.

Cap installation involves setting the cap on 2" thick steel shims that provide room for a bedding layer of grout between the top of the columns and the bottom of the cap. Next, the four threadbar connectors are fastened snug tight from above. The bedding layer receives a nominally 6"-wide peripheral placement of dry pack grout to act as a "stay-in-place" form for the subsequent pressure pumping of fluid grout for the majority of the connection. After the peripheral dry pack layer has sufficiently cured, fluid grout is pressure-pumped into one of the inlet tubes until the vent tubes indicate the connection has been fully grouted. All the inlet locations are "topped off" to ensure

complete grouting. After sufficient grout strength has been obtained, the temporary top threadbar hardware is removed and grouted over, and superstructure erection may commence.

Precast cap fabrication is underway at the time of authoring this paper. The precast bent caps are being fabricated at a plant approximately 140 miles south of the project. (See Figure 17.) A series of mockups were developed to establish the reliability of the grouting method and to provide contractor and TxDOT personnel experience with the system. TxDOT is working closely with the contractor to meet unique construction challenges of this project.

ACKNOWLEDGMENT

Although TxDOT has developed design methodology to achieve moment capacity with precast bent caps, the capacity of these connections to handle seismic forces has not been established. Limited research with regard to seismic capacity has been done by Eric Matsumoto, P.E., Ph.D. at California State University, Sacramento. Suitability and design of precast bent caps for seismic applications need to be confirmed through further research.

REFERENCES

1. Matsumoto, E. E.; Waggoner, M. C.; Sumen, G.; Kreger, M. E.; Wood, S. L.; and Breen, J. E. *Development of a Precast Bent Cap System*. Research Report 1748-2. Texas Department of Transportation and FHWA, US Department of Transportation, 2001.

LIST OF FIGURES

- FIGURE 1** Epoxy-coated U-shaped reinforcing bars projecting from the piles into the slots.
FIGURE 2 Precast caps on the Redfish Bay and Morris and Cummings Cut Bridges.
FIGURE 3 Schematic of Redfish Bay Connection
FIGURE 4 Schematic of Precast Cap on US 290 Ramp E-3
FIGURE 5 Precast cap on US 290 Ramp E-3.
FIGURE 6 Pierce Elevated Cap to Column Connection Details
FIGURE 7 Original bent caps cut off at the top of the columns.
FIGURE 8 Research Project 1748 Detail for Single-line Grout Pocket on Pile (Embedded Option)
FIGURE 9 Research Project 1748 Detail for Double-line Grout Pocket on Column (Surface-flush Option)
FIGURE 10 Research Project 1748 Detail for Grouted Vertical Duct on Pile (Embedded Option)
FIGURE 11 Research Project 1748 Detail for Grouted Vertical Duct on Column (Surface-flush Option)
FIGURE 12 Research Project 1748 Detail for Bolted Connection on Pile (Surface-flush Option)
FIGURE 13 Precast bent caps and a temporary construction bridge.
FIGURE 14 Lake Ray Hubbard Schematic Duct Placement
FIGURE 15 Lake Ray Hubbard Reinforcing
FIGURE 16 Lake Belton Bridge substructure with large hammer-head bent caps.
FIGURE 17 – Lake Belton Schematic Reinforcing
FIGURE 18 Lake Belton Schematic Duct Placement
FIGURE 19 – Lake Belton Cap Photo



FIGURE 1 Epoxy-coated U-shaped reinforcing bars projecting from the piles into the slots.



FIGURE 2 Precast caps on the Redfish Bay and Morris and Cummings Cut Bridges.

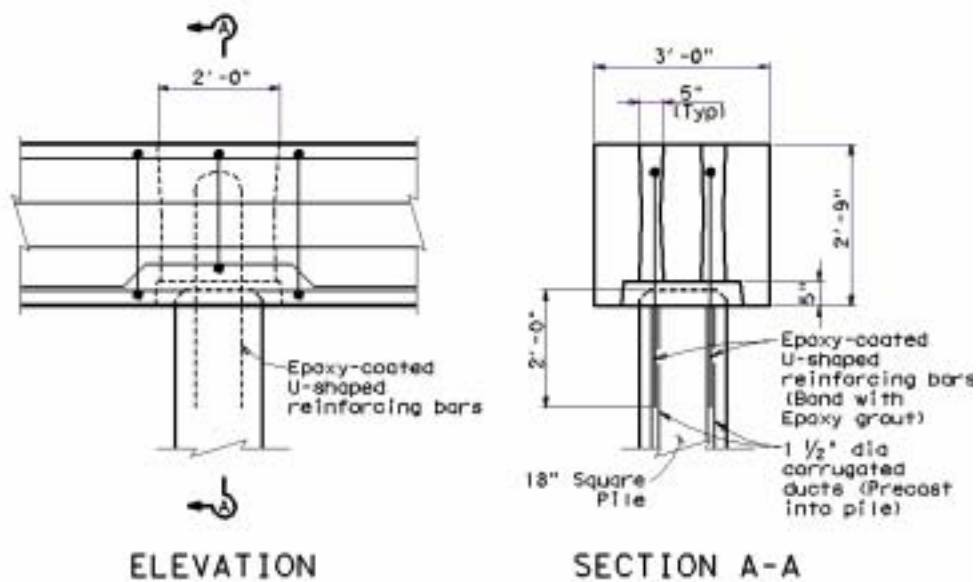


FIGURE 3 – Schematic of Redfish Bay Connection

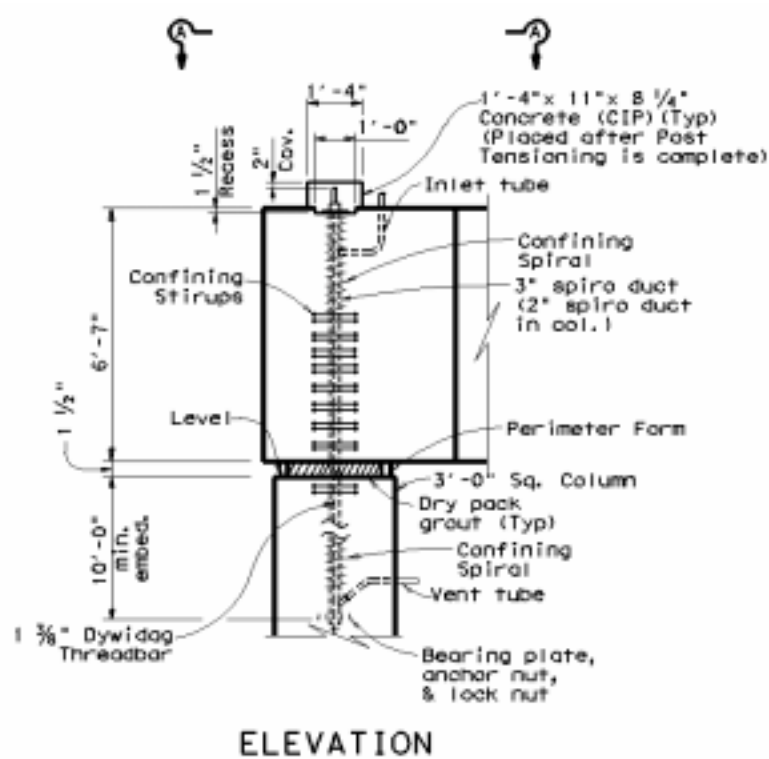


FIGURE 4 – Schematic of Precast Cap on US 290 Ramp E-3



FIGURE 5 Precast cap on US 290 Ramp E-3.

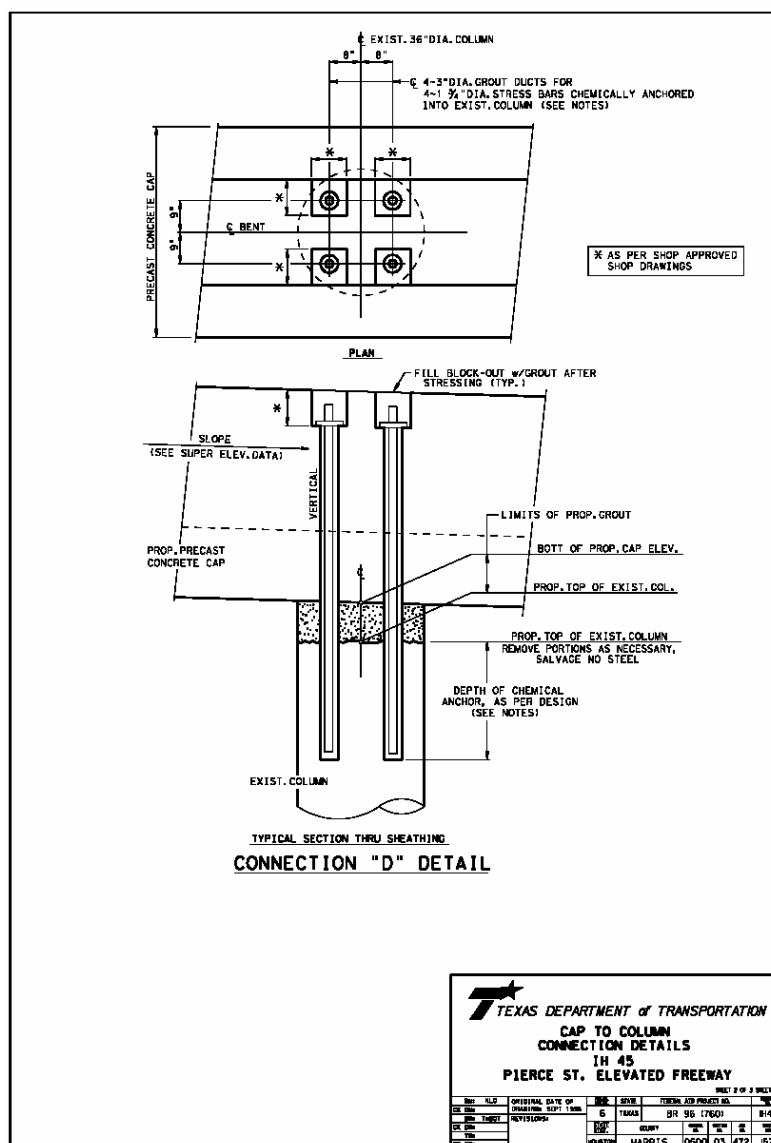


FIGURE 6 – Pierce Elevated Cap to Column Connection Details



FIGURE 7 Original bent caps saw-cut at the top of the columns.

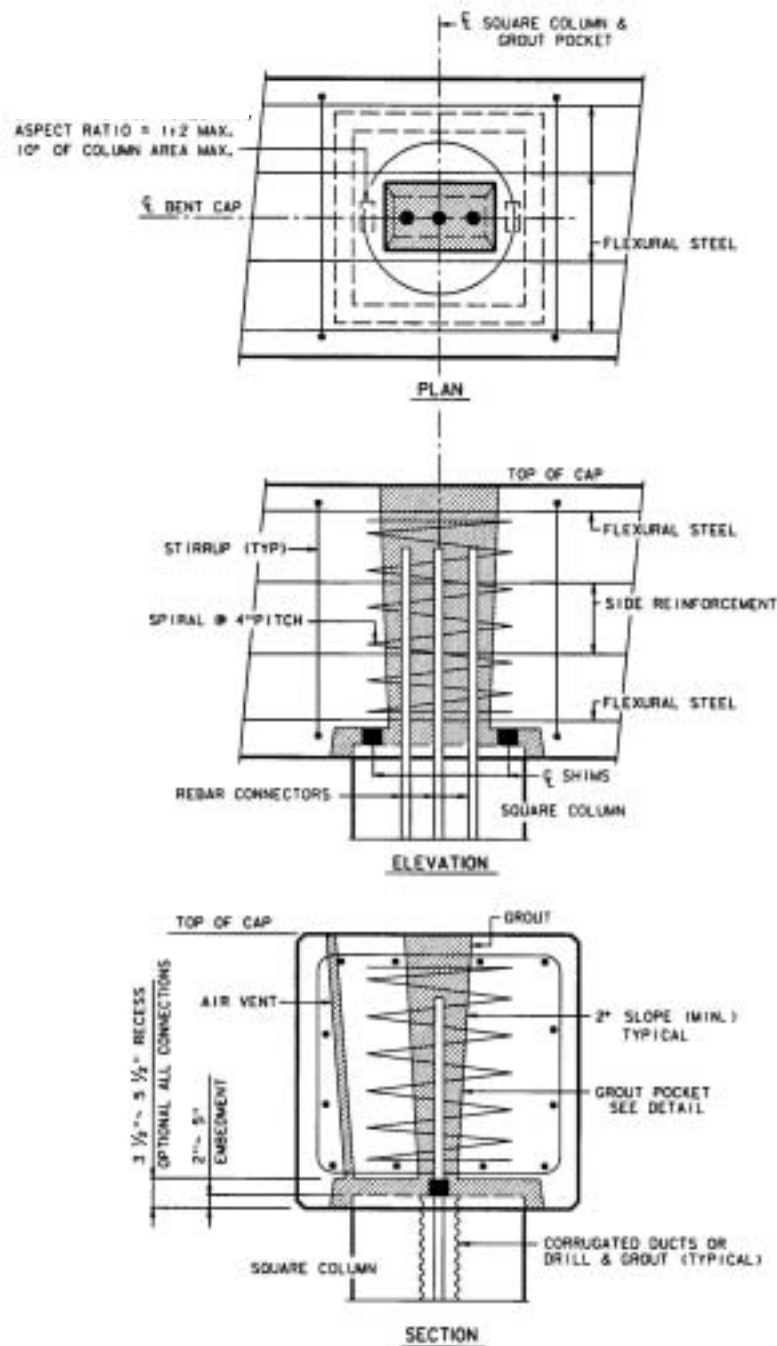


FIGURE 8 Research Project 1748 Detail for Single-line Grout Pocket on Pile (Embedded Option)

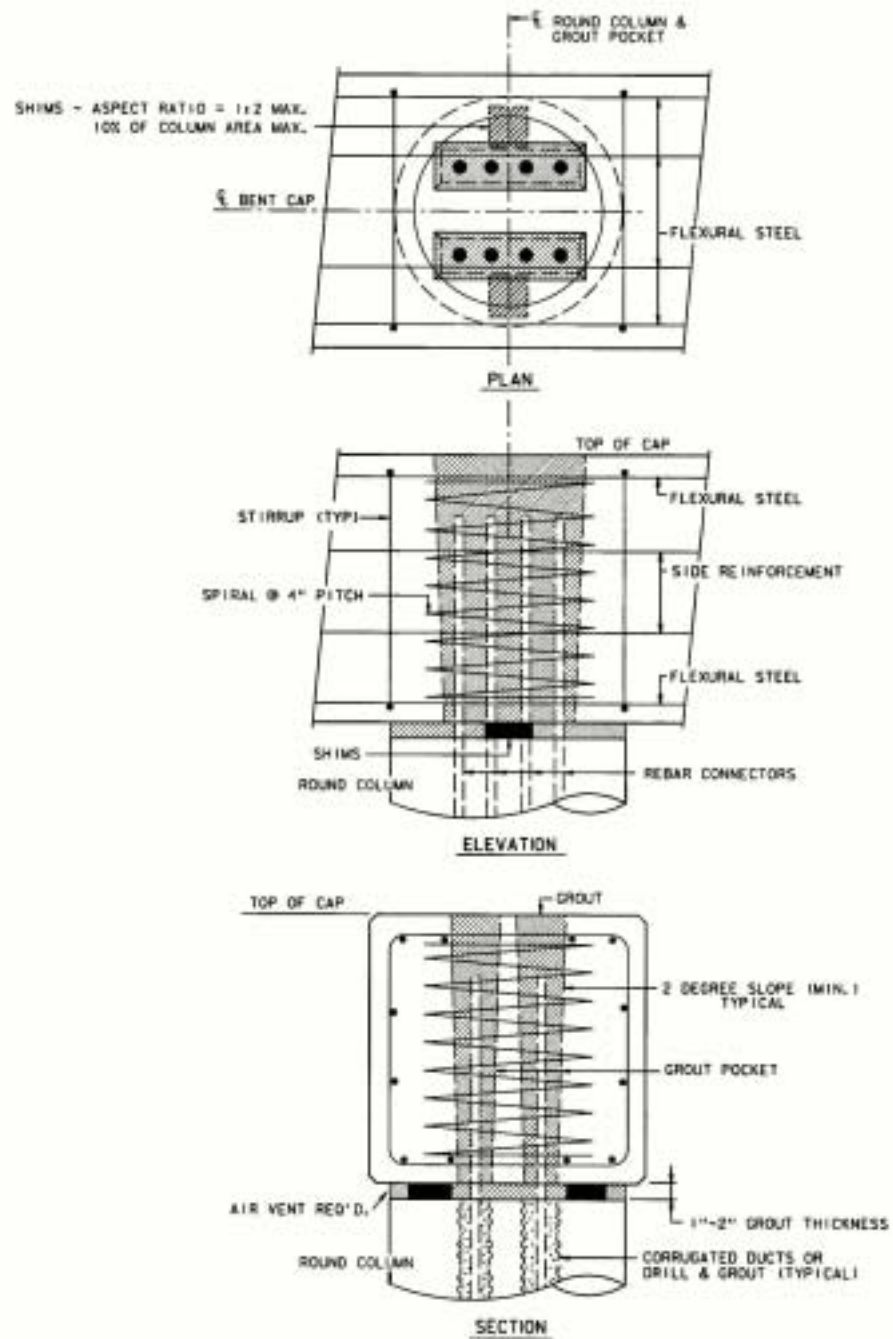


FIGURE 9 Research Project 1748 Detail for Double-line Grout Pocket on Column (Surface-flush Option)

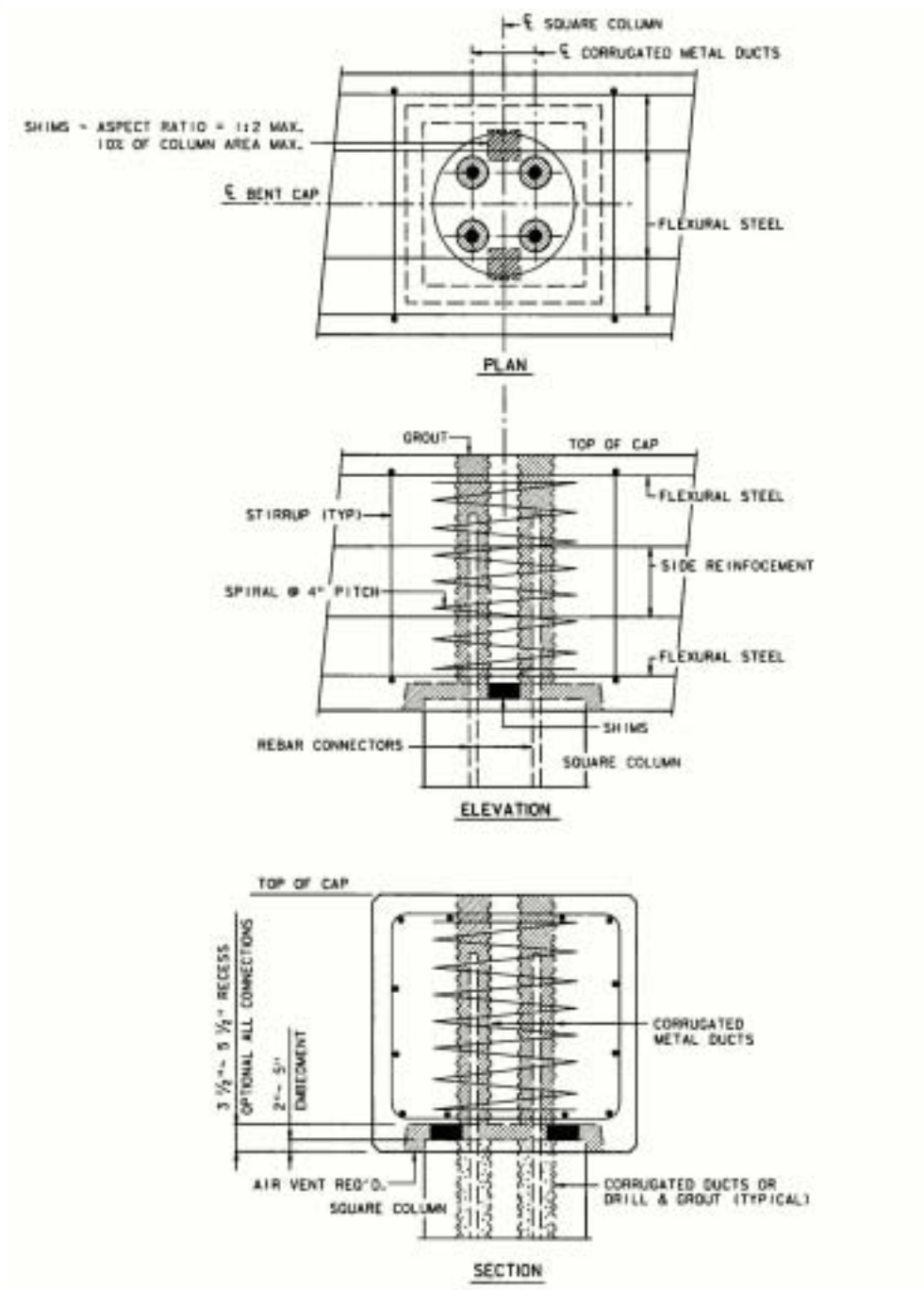


FIGURE 10 Research Project 1748 Detail for Grouted Vertical Duct on Pile (Embedded Option)

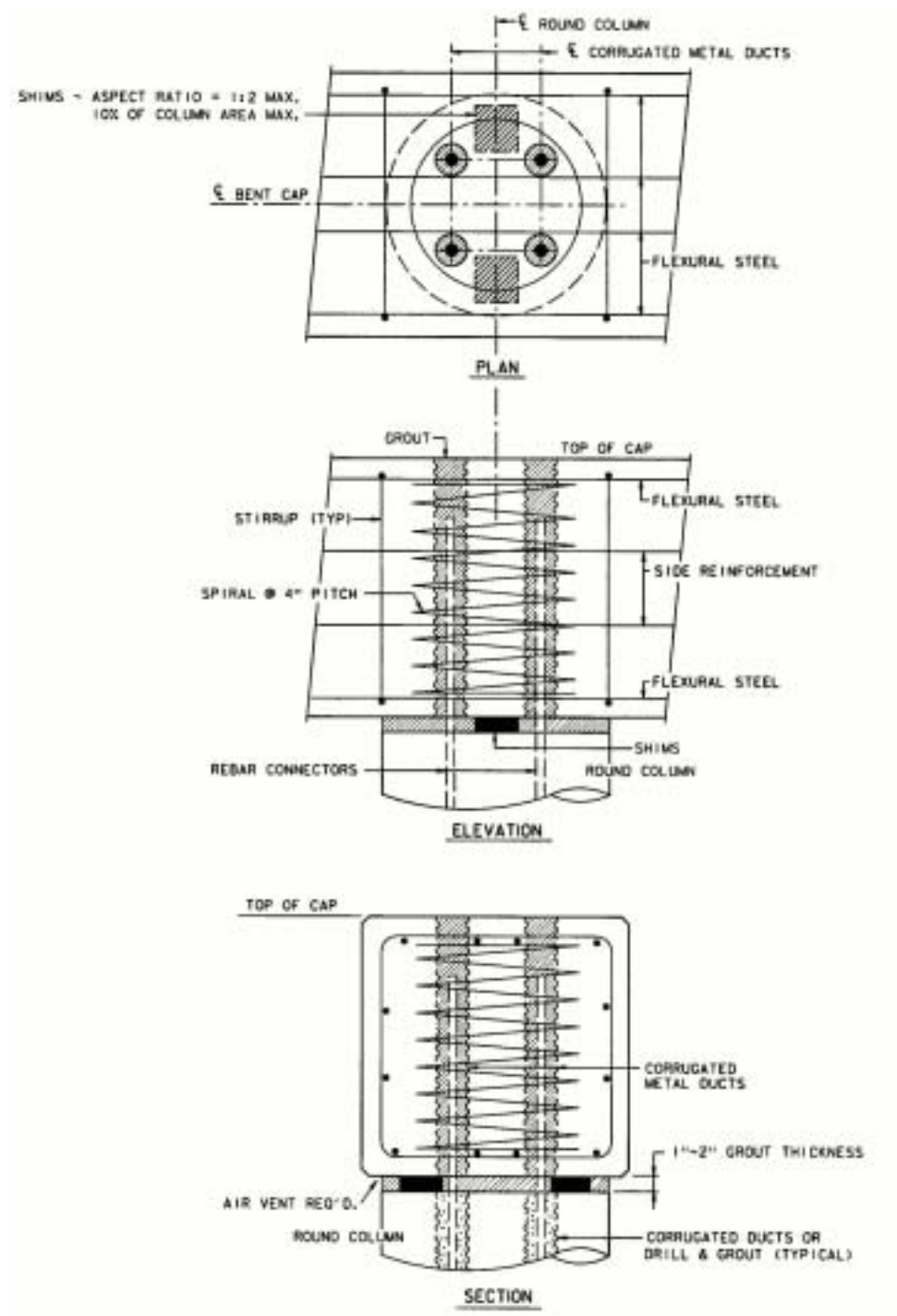


FIGURE 11 Research Project 1748 Detail for Grouted Vertical Duct on Column (Surface-flush Option)

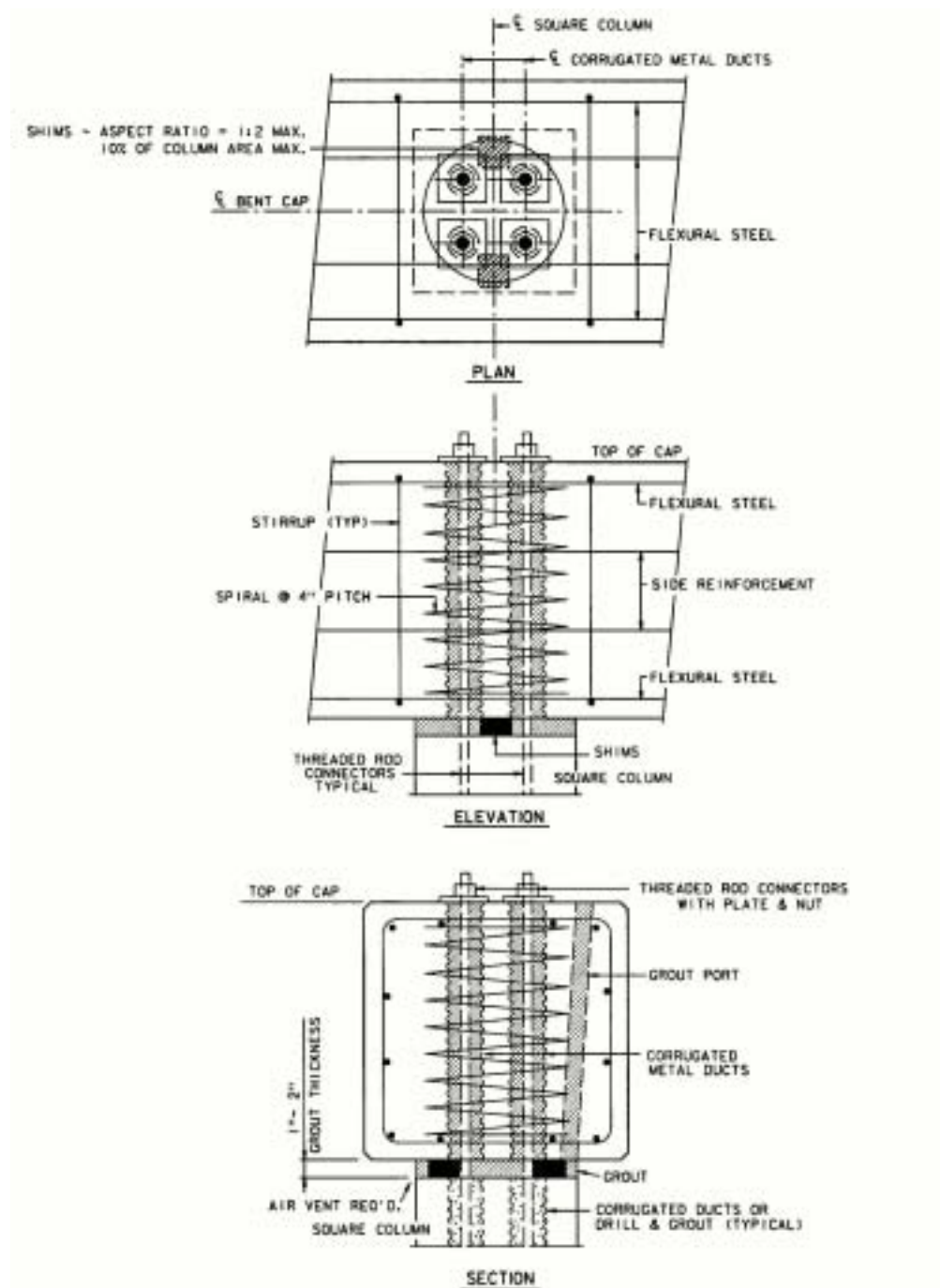


FIGURE 12 Research Project 1748 Detail for Bolted Connection on Pile (Surface-flush Option)



FIGURE 13 Precast bent caps and a temporary construction bridge.

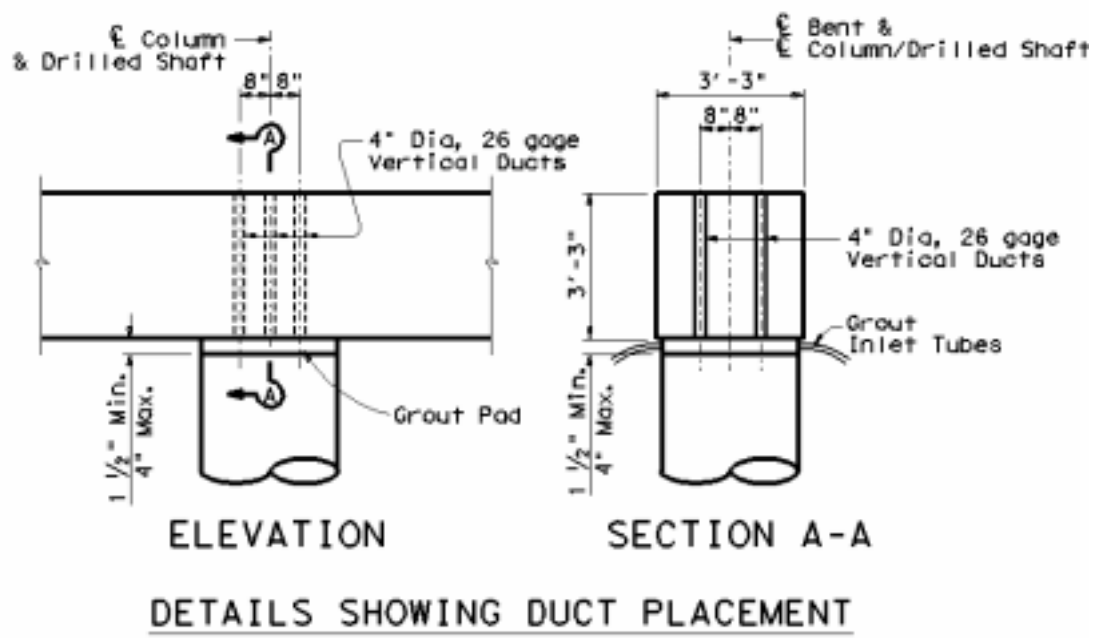


FIGURE 14 Lake Ray Hubbard Schematic Duct Placement

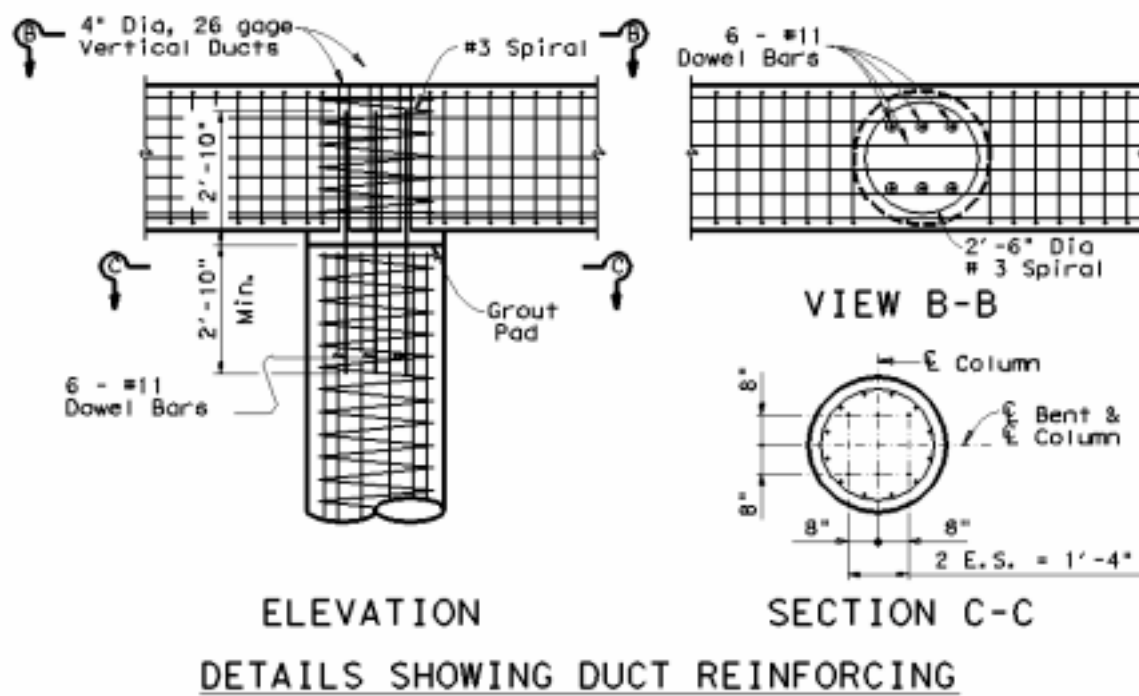


FIGURE 15 Lake Ray Hubbard Schematic Reinforcing

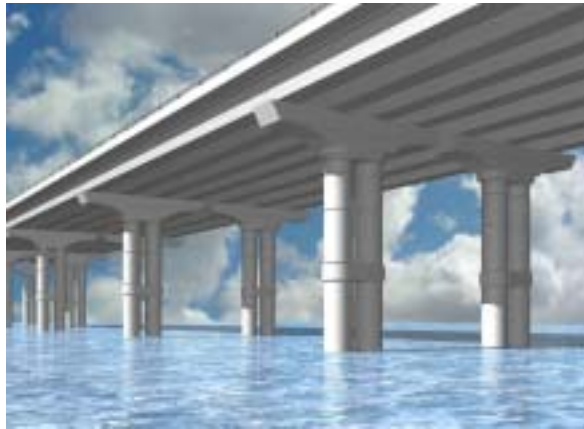
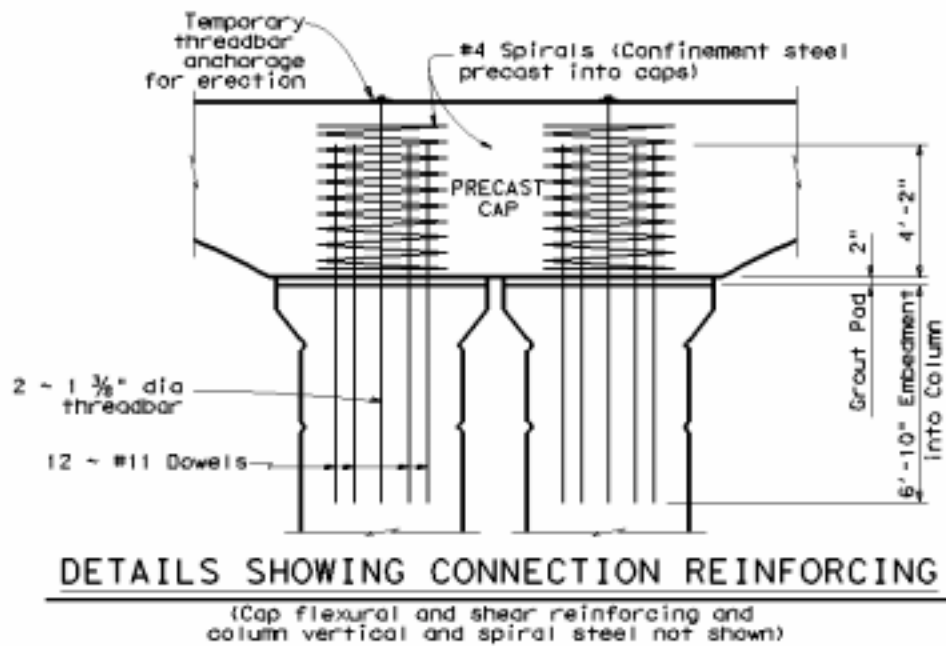


FIGURE 16 Lake Belton Bridge substructure with large hammer-head bent caps.

**FIGURE 17 Lake Belton Schematic Reinforcing**

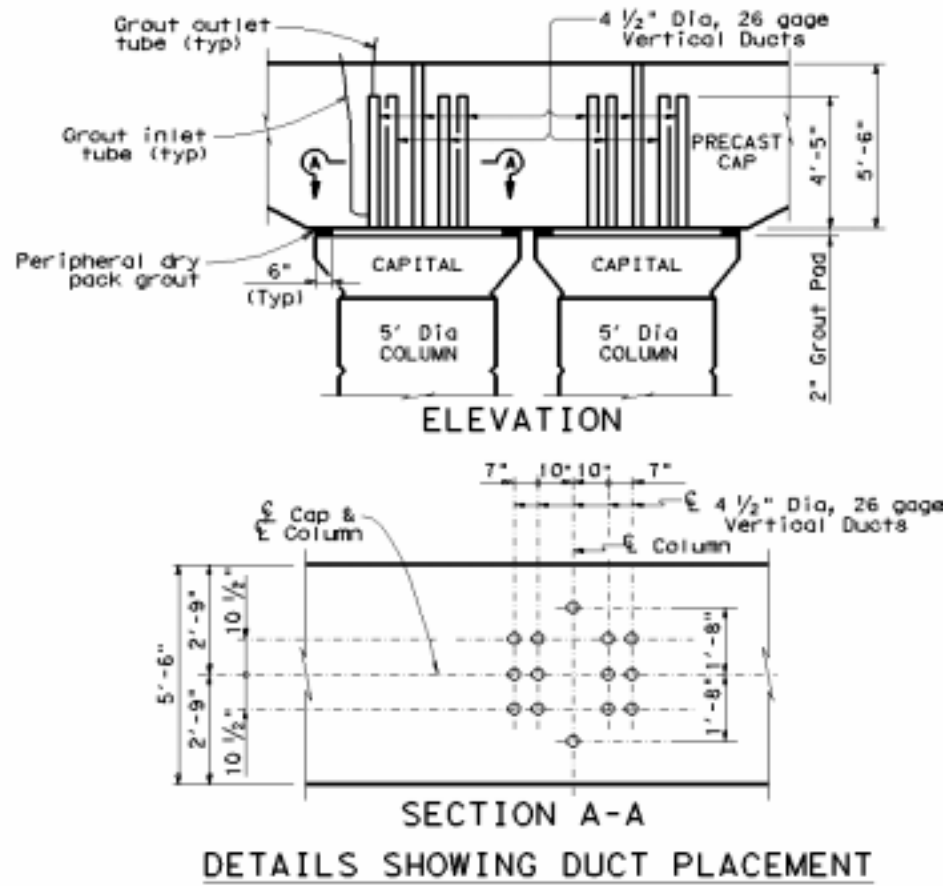


FIGURE 18 Lake Belton Schematic Duct Placement



FIGURE 19 Lake Belton Cap Photo